CLAIMS

What is claimed is:

1. A method for estimating carrier frequency offset in an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

receiving a preamble including a plurality of short training symbols;

sampling said short training symbols of said preamble at a first rate; and

correlating at least two adjacent short training symbols to generate a correlation signal.

2. The method of claim 1 further comprising normalizing said correlation signal to generate a normalized correlation signal.

3. The method of claim 2 wherein said normalizing step further comprises dividing said correlation signal by an energy of at least one of said adjacent short training symbols.

4. The method of claim 2 further comprising:

repeating said sampling, correlating and normalizing steps for all of said short training symbols; and

identifying a maximum value of said normalized correlation signal during said short training symbols.

5. The method of claim 4 further comprising multiplying said maximum value of said normalized correlation signal by a threshold value to identify left and right edges of a plateau defined by said normalized correlation signal.

6. The method of claim 5 wherein said threshold value is greater than zero and less than one.

7. The method of claim 5 further comprising identifying left and right time index values corresponding to said left and right edges.

8. The method of claim 7 further comprising identifying a center time index value using said left and right time index values.

9. The method of claim 8 further comprising using said center time index value and a correlation value corresponding to said center time index value to calculate said carrier frequency offset.

10. The method of claim 9 further comprising:

calculating a first value by dividing an imaginary component of said correlation value at said center time index value by a real component of said correlation value at said center time index value; and

calculating an arctangent of said first value.

11. The method of claim 1 wherein said method is a software method.

12. The method of claim 10 further comprising calculating said carrier frequency offset by dividing said arctangent by $2\pi T_{short}$ wherein T_{short} is the period of said short training symbols.

13. The method of claim 1 wherein said preamble forms part of an orthogonal frequency division multiplex (OFDM) packet.

14. A method for estimating carrier frequency offset in an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

receiving a preamble including a plurality of short training symbols;

sampling said short training symbols of said preamble using a sampling window; and

correlating a first half of said sampling window with a second half of said sampling window to generate a correlation signal.

15. The method of claim 14 wherein said sampling window has a period that is equal to a duration of two short training symbols.

16. The method of claim 14 further comprising normalizing said correlation signal to generate a normalized correlation signal.

17. The method of claim 16 wherein said normalizing step further comprises dividing said correlation signal by an energy of at least one of said first and second halves of said sampling window.

18. The method of claim 17 further comprising repeating said sampling, correlating and normalizing steps for all of said short training symbols.

19. The method of claim 18 further comprising identifying a maximum value of said normalized correlation signal during said short training symbols.

20. The method of claim 19 further comprising multiplying said maximum value of said normalized correlation signal by a threshold value to identify left and right edges of a plateau defined by said normalized correlation signal.

21. The method of claim 20 wherein said threshold value is greater than zero and less than one.

22. The method of claim 20 further comprising identifying left and right time index values corresponding to said left and right edges.

23. The method of claim 22 further comprising identifying a center time index value using said left and right time index values.

24. The method of claim 23 further comprising using said center time index value and a correlation value corresponding to said center time index value to calculate said carrier frequency offset.

25. The method of claim 24 further comprising calculating a first value by dividing an imaginary component of said correlation value at said center time index value by a real component of said correlation value at said center time index value and calculating an arctangent of said first value.

26. The method of claim 14 wherein said method is a software method.

27. The method of claim 25 further comprising calculating said carrier frequency offset by dividing said arctangent by $2\pi T_{short}$ wherein T_{short} is the period of said short training symbols.

28. The method of claim 14 wherein said preamble forms part of an orthogonal frequency division multiplex (OFDM) packet.

29. A method for estimating symbol timing of a guard interval in an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

receiving a preamble including a plurality of short training symbols;

sampling said short training symbols of said preamble at a first rate;

correlating a first short training symbol with a second short training symbol that is adjacent to said first short training symbol and generating a correlation signal;

normalizing said correlation signal to generate a normalized correlation signal; and

calculating a mean absolute difference of said normalized correlation signal.

30. The method of claim 29 further comprising repeating said sampling, correlating and normalizing steps for all of said short training symbols.

31. The method of claim 30 further comprising multiplying said maximum value of said normalized correlation signal by a threshold value to identify left and right edges of a plateau defined by said normalized correlation signal.

32. The method of claim 31 further comprising identifying left and right time index values corresponding to said left and right edges.

33. The method of claim 32 further comprising identifying a center time index value using said left and right time index values and calculating a value K that is based on said left and right time index values divided by 2.

34. The method of claim 29 wherein said method is a software method.

35. The method of claim 33 further comprising calculating said mean absolute difference from K/2 before said center time index value to K/2 after said center time index value.

36. The method of claim 35 further comprising identifying a guard interval time index value when an absolute difference between one normalized correlation value and a preceding normalized correlation value exceeds said mean absolute difference multiplied by a threshold value.

37. The method of claim 36 further comprising adjusting said guard interval time index by a tolerance factor.

38. A method for estimating carrier frequency offset in an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

sampling short training symbols of a preamble of a data packet to generate a received signal; and

quantizing sign bits of real and imaginary components of said received signal.

39. The method of claim 38 further comprising correlating said quantized sign bits of at least two adjacent short training symbols to generate a correlation signal.

40. The method of claim 38 further comprising generating a filtered sum of an absolute value of a real component of said correlation signal and an absolute value of an imaginary component of said correlation signal.

41. The method of claim 40 wherein said filtered sum is generated by a single pole filter.

42. The method of claim 40 further comprising identifying a local maximum value of said filtered sum during said short training symbols.

43. The method of claim 42 wherein said local maximum value is identified by updating and storing said filtered sums and by comparing at least one filtered sum to a prior filtered sum and to a subsequent filtered sum.

44. The method of claim 42 further comprising multiplying said local maximum value of said filtered sum by a threshold value to identify a right edge of a plateau wherein said threshold value is greater than zero and less than one.

45. The method of claim 38 wherein said method is a software method.

46. The method of claim 44 further comprising:

identifying a right time index value corresponding to said right edge; and

calculating symbol timing from said right time index value.

47. The method of claim 40 further comprising identifying a maximum value of said filtered sum during said short training symbols.

48. The method of claim 47 further comprising identifying said maximum value by updating and storing said filtered sums and by comparing at least one filtered sum to a prior filtered sum and to a subsequent filtered sum.

49. The method of claim 48 further comprising:

identifying a time index value corresponding to said maximum value; and

identifying a correlation signal value corresponding to said time index value.

50. The method of claim 49 further comprising:

calculating an imaginary component of said correlation signal value corresponding to said time index value;

calculating a real component of said correlation signal value corresponding to said time index value;

dividing said imaginary component by said real component to generate a quotient; and

calculating an arctangent of said quotient to generate a coarse carrier frequency offset estimate.

51. The method of claim 50 further comprising:

multiplying said received signal by $e^{-jn\omega_\Delta}$ where ω_Δ is said coarse carrier frequency offset estimate and n is a time index.

52. A method for estimating carrier frequency offset in an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

generating a symbol timing estimate that identifies a start time of first and second long training symbols of a preamble of a data packet;

sampling said first and second long training symbols of said preamble to generate a received signal;

correlating said first and second long training symbols to generate a correlation signal; and

calculating a fine carrier frequency offset from said correlation signal.

53. The method of claim 52 wherein said step of calculating further comprises:

calculating an imaginary component of said correlation signal;

calculating a real component of said correlation signal;

dividing said imaginary component by said real component to generate a quotient; and

calculating an arctangent of said quotient to generate said fine carrier frequency offset estimate.

54. The method of claim 53 further comprising updating a sampling clock with said fine carrier frequency offset estimate.

55. A method for updating channel estimates in an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

generating channel estimates for an orthogonal frequency division multiplexing subcarrier as a function of subcarrier index values;

generating a complex number by summing a product of frequency domain signals and said channel estimates for each of said subcarrier index values and dividing said sum by a sum of a squared absolute value of said channel estimate for each of said subcarrier index values; and

multiplying said complex number by said channel estimates to generate updated channel estimates.

56. The method of claim 55 further comprising using said updated channel estimates in a frequency equalizer for data detection.

57. A method for adapting a carrier frequency offset estimate in an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

generating channel estimates for an orthogonal frequency division multiplexing subcarrier as a function of subcarrier index values;

generating a complex number by summing a product of frequency domain signals and said channel estimates for each of said subcarrier index values and dividing said sum by a sum of a squared absolute value of said channel estimate for each of said subcarrier index values; and

calculating an imaginary component of said complex number.

58. The method of claim 57 further comprising multiplying said imaginary component by an adaptation parameter to generate a product.

59. The method of claim 58 further comprising adding said product to a prior carrier frequency offset estimate to produce an adapted carrier frequency offset estimate.

60. A symbol timing estimator of a guard interval for an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

receiving means for receiving a preamble including a plurality of short training symbols;

sampling means for sampling said short training symbols of said preamble at a first rate;

correlating means for correlating a first short training symbol with a second short training symbol that is adjacent to said first short training symbol and generating a correlation signal;

normalizing means for normalizing said correlation signal to generate a normalized correlation signal; and

first calculating means for calculating a mean absolute difference of said normalized correlation signal.

61. The symbol timing estimator of claim 60 further comprising first multiplying means for multiplying said maximum value of said normalized correlation signal by a threshold value to identify left and right edges of a plateau defined by said normalized correlation signal.

62. The symbol timing estimator of claim 61 further comprising first identifying means for identifying left and right time index values corresponding to said left and right edges.

63. The symbol timing estimator of claim 62 further comprising second identifying means for identifying a center time index value using said left and right time index values.

64. The symbol timing estimator of claim 63 further comprising second calculating means for calculating a value K that is based on said left and right time index values divided by 2.

65. The symbol timing estimator of claim 64 further comprising third calculating means for calculating said mean absolute difference from K/2 before said center time index value to K/2 after said center time index value.

66. The symbol timing estimator of claim 65 further comprising third identifying means for identifying a guard interval time index value when an absolute difference between one normalized correlation value and a preceding normalized correlation value exceeds said mean absolute difference multiplied by a threshold value.

67. The symbol timing estimator of claim 66 further comprising adjusting means for adjusting said guard interval time index by a tolerance factor.

68. A carrier frequency offset estimator for an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

sampling means for sampling short training symbols of a preamble of a data packet to generate a received signal; and

quantizing means for quantizing sign bits of real and imaginary components of said received signal.

69. The carrier frequency offset estimator of claim 68 further comprising correlating means for correlating said quantized sign bits of at least two adjacent short training symbols to generate a correlation signal.

70. The carrier frequency offset estimator of claim 68 further comprising filtered sum generating means for generating a filtered sum of an absolute value of a real component of said correlation signal and an absolute value of an imaginary component of said correlation signal.

71. The carrier frequency offset estimator of claim 70 wherein said filtered sum is generated by a single pole filter.

72. The carrier frequency offset estimator of claim 70 further comprising first identifying means for identifying a local maximum value of said filtered sum during said short training symbols.

73. The carrier frequency offset estimator of claim 72 wherein said local maximum value is identified by updating and storing said filtered sums and by comparing at least one filtered sum to a prior filtered sum and to a subsequent filtered sum.

74. The carrier frequency offset estimator of claim 72 further comprising first multiplying means for multiplying said local maximum value of said filtered sum by a threshold value to identify a right edge of a plateau.

75. The carrier frequency offset estimator of claim 74 wherein said threshold value is greater than zero and less than one.

76. The carrier frequency offset estimator of claim 74 further comprising:

second identifying means for identifying a right time index value corresponding to said right edge; and

first calculating means for calculating symbol timing from said right time index value.

77. The carrier frequency offset estimator of claim 70 further comprising third identifying means for identifying a maximum value of said filtered sum during said short training symbols.

78. The carrier frequency offset estimator of claim 77 further comprising fourth identifying means for identifying said maximum value by updating and storing said filtered sums and by comparing at least one filtered sum to a prior filtered sum and to a subsequent filtered sum.

79. The carrier frequency offset estimator of claim 78 further comprising:

fifth identifying means for identifying a time index value corresponding to said maximum value; and

sixth identifying means for identifying a correlation signal value corresponding to said time index value.

80. The carrier frequency offset estimator of claim 79 further comprising:

second calculating means for calculating an imaginary component of said correlation signal value corresponding to said time index value;

third calculating means for calculating a real component of said correlation signal value corresponding to said time index value;

dividing means for dividing said imaginary component by said real component to generate a quotient; and

fourth calculating means for calculating an arctangent of said quotient to generate a coarse carrier frequency offset estimate.

81. The carrier frequency offset estimator of claim 80 further comprising:

second multiplying means for multiplying said received signal by $e^{-jn\omega_\Delta}$ where ω_Δ is said coarse carrier frequency offset estimate and n is a time index.

82. A carrier frequency offset estimator for an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

symbol timing generating means for generating a symbol timing estimate that identifies a start time of first and second long training symbols of a preamble of a data packet;

sampling means for sampling said first and second long training symbols of said preamble to generate a received signal;

correlating means for correlating said first and second long training symbols to generate a correlation signal; and

first calculating means for calculating a fine carrier frequency offset from said correlation signal.

83. The carrier frequency offset estimator of claim 82 wherein said first calculating means calculates an imaginary component of said correlation signal, calculates a real component of said correlation signal, divides said imaginary component by said real component to generate a quotient, and calculates an arctangent of said quotient to generate said fine carrier frequency offset estimate.

84. The carrier frequency offset estimator of claim 83 further comprising updating means for updating a sampling clock with said fine carrier frequency offset estimate.

85. A channel estimate updating circuit for an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

channel estimate generating means for generating channel estimates for an orthogonal frequency division multiplexing subcarrier as a function of subcarrier index values;

complex number generating means for generating a complex number by summing a product of frequency domain signals and said channel estimates for each of said subcarrier index values and dividing said sum by a sum of a squared absolute value of said channel estimate for each of said subcarrier index values; and

first multiplying means for multiplying said complex number by said channel estimates to generate updated channel estimates.

86. The channel estimate updating circuit of claim 85 wherein said updated channel estimates are used in a frequency equalizer for data detection.

87. A carrier frequency offset estimate adaptor for an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

channel estimate generating means for generating channel estimates for an orthogonal frequency division multiplexing subcarrier as a function of subcarrier index values;

complex number generating means for generating a complex number by summing a product of frequency domain signals and said channel estimates for each of said subcarrier index values and dividing said sum by a sum of a squared absolute value of said channel estimate for each of said subcarrier index values; and

first calculating means for calculating an imaginary component of said complex number.

88. The carrier frequency offset estimate adaptor of claim 87 further comprising first multiplying means for multiplying said imaginary component by an adaptation parameter to generate a product.

89. The carrier frequency offset estimate adaptor of claim 88 further comprising first adding means for adding said product to a prior carrier frequency offset estimate to produce an adapted carrier frequency offset estimate.

90. A symbol timing estimator of a guard interval for an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

a receiver that receiving a preamble including a plurality of short training symbols and samples said short training symbols of said preamble at a first rate;

a correlator that correlates a first short training symbol with a second short training symbol that is adjacent to said first short training symbol and generating a correlation signal;

a normalizer that normalizes said correlation signal to generate a normalized correlation signal; and

a first calculator that calculates a mean absolute difference of said normalized correlation signal.

91. The symbol timing estimator of claim 90 further comprising a first multiplier that multiplies said maximum value of said normalized correlation signal by a threshold value to identify left and right edges of a plateau defined by said normalized correlation signal.

92. The symbol timing estimator of claim 91 further comprising a first identifier circuit that identifies left and right time index values corresponding to said left and right edges.

93. The symbol timing estimator of claim 92 further comprising a second identifier circuit that identifies a center time index value using said left and right time index values.

94. The symbol timing estimator of claim 93 further comprising a second calculator that calculates a value K that is based on said left and right time index values divided by 2.

95. The symbol timing estimator of claim 94 further comprising a third calculator that calculates said mean absolute difference from K/2 before said center time index value to K/2 after said center time index value.

96. The symbol timing estimator of claim 95 further comprising a third identifier circuit that identifies a guard interval time index value when an absolute difference between one normalized correlation value and a preceding normalized correlation value exceeds said mean absolute difference multiplied by a threshold value.

97. The symbol timing estimator of claim 96 further comprising a guard interval adjustor that adjusts said guard interval time index by a tolerance factor.

98. A carrier frequency offset estimator for an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

a sampler that samples short training symbols of a preamble of a data packet to generate a received signal; and

a quantizer that quantizes sign bits of real and imaginary components of said received signal.

99. The carrier frequency offset estimator of claim 98 further comprising a correlator that correlates said quantized sign bits of at least two adjacent short training symbols to generate a correlation signal.

100. The carrier frequency offset estimator of claim 98 further a filtered sum generator that generates a filtered sum of an absolute value of a real component of said correlation signal and an absolute value of an imaginary component of said correlation signal.

101. The carrier frequency offset estimator of claim 100 wherein said filtered sum is generated by a single pole filter.

102. The carrier frequency offset estimator of claim 100 further comprising a first identifier circuit that identifies a local maximum value of said filtered sum during said short training symbols.

103. The carrier frequency offset estimator of claim 102 wherein said local maximum value is identified by updating and storing said filtered sums and by comparing at least one filtered sum to a prior filtered sum and to a subsequent filtered sum.

104. The carrier frequency offset estimator of claim 102 further comprising a first multiplier circuit that multiplies said local maximum value of said filtered sum by a threshold value to identify a right edge of a plateau.

105. The carrier frequency offset estimator of claim 104 wherein said threshold value is greater than zero and less than one.

106. The carrier frequency offset estimator of claim 104 further comprising:

second identifier circuit that identifies a right time index value corresponding to said right edge; and

a first calculator that calculates symbol timing from said right time index value.

107. The carrier frequency offset estimator of claim 100 further comprising a third identifier that identifies a maximum value of said filtered sum during said short training symbols.

108. The carrier frequency offset estimator of claim 107 further comprising fourth identifying means for identifying said maximum value by updating and storing said filtered sums and by comparing at least one filtered sum to a prior filtered sum and to a subsequent filtered sum.

109. The carrier frequency offset estimator of claim 108 further comprising:

a fifth identifier that identifies a time index value corresponding to said maximum value; and

a sixth identifier that identifies a correlation signal value corresponding to said time index value.

110. The carrier frequency offset estimator of claim 109 further comprising:

a second calculator that calculates an imaginary component of said correlation signal value corresponding to said time index value;

a third calculator that calculates a real component of said correlation signal value corresponding to said time index value;

a divider that divides said imaginary component by said real component to generate a quotient; and

a fourth calculator that calculates an arctangent of said quotient to generate a coarse carrier frequency offset estimate.

111. The carrier frequency offset estimator of claim 110 further comprising:

a second multiplier that multiplies said received signal by $e^{-jn\omega_{\Delta}}$ where ω_{Δ} is said coarse carrier frequency offset estimate and n is a time index.

112. A carrier frequency offset estimator for an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

a symbol timing generator that produces a symbol timing estimate that identifies a start time of first and second long training symbols of a preamble of a data packet;

a sampling circuit that samples said first and second long training symbols of said preamble to generate a received signal;

a correlator that correlates said first and second long training symbols to generate a correlation signal; and

a first calculator that calculates a fine carrier frequency offset from said correlation signal.

113. The carrier frequency offset estimator of claim 112 wherein said first calculator calculates an imaginary component of said correlation signal, calculates a real component of said correlation signal, divides said imaginary component by said real component to generate a quotient, and calculates an arctangent of said quotient to generate said fine carrier frequency offset estimate.

114. The carrier frequency offset estimator of claim 113 further comprising a sampling clock updater that updates a sampling clock with said fine carrier frequency offset estimate.

115. A channel estimate updating circuit for an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

a channel estimator that generates channel estimates for an orthogonal frequency division multiplexing subcarrier as a function of subcarrier index values;

a complex number generator that generates a complex number by summing a product of frequency domain signals and said channel estimates for each of said subcarrier index values and dividing said sum by a sum of a squared absolute value of said channel estimate for each of said subcarrier index values; and

a first multiplier that multiplies said complex number by said channel estimates to generate updated channel estimates.

116. The channel estimate updating circuit of claim 115 wherein said updated channel estimates are used in a frequency equalizer for data detection.

117. A carrier frequency offset estimate adaptor for an orthogonal frequency division multiplexing receiver of a wireless local area network, comprising:

a channel estimator that generates channel estimates for an orthogonal frequency division multiplexing subcarrier as a function of subcarrier index values;

a complex number generator that generates a complex number by summing a product of frequency domain signals and said channel estimates for each of said subcarrier index values and dividing said sum by a sum of a squared absolute value of said channel estimate for each of said subcarrier index values; and

a first calculator that calculates an imaginary component of said complex number.

118. The carrier frequency offset estimate adaptor of claim 117 further comprising a first multiplier that multiplies said imaginary component by an adaptation parameter to generate a product.

119. The carrier frequency offset estimate adaptor of claim 118 further comprising a first adder that adds said product to a prior carrier frequency offset estimate to produce an adapted carrier frequency offset estimate.